Establishing Safety of Energy Storage — an Overview of UL Safety Standards



Laurie Florence
Principal Engineer Large Format Batteries, Fuel Cells and Capacitors
Commercial and Industrial: EP & C
UL LLC

CPUC - Energy Storage Workshop, August 19, 2015

Leader in Advanced Battery Safety Science









UL 2271: Light Electric Vehicles

UL 9540: Energy Storage Systems

UL 2580: Electric Vehicles



Agenda



Mitigating risk – a safety approach

- Identifying and addressing hazards
- UL 1973 and safety approach

Introduction to UL 9540

- UL 9540 Scope
- UL 9540 Overview
- UL 9540 Status

Certification options

Certification and labelling options

US DOE and code activities

- US DOE activities
- Code activities

Mitigating risk - A safety approach





the potential hazards associated with ESSs?



Energy

- Fire
- Arc flash
- Explosion



Electrical

Electric shock



Mechanical

- Over pressure
- Noise
- Moving parts



Chemical

 Toxic and hazardous substance exposure





Safety design analysis

- Failure Modes and Effects Analysis (FMEA), IEC 60812
 - ID Failure mode
 - Effect/Severity of failure
 - Probability of occurrence of failure
 - Detection/mitigation scheme effectiveness

Reliability Protection Number (RPN)

 $RPN = S \times O \times D$

Where

S – Severity of failure

O – Probability of occurrence

D - Reliability of detection

F	Item/ Func- tion			Poten tial failure mode	Potentic effect (: failure		00>01-4>	0_000	Potential cause(s)/ mechanis m(s) of failure	cause(s)/ cause(s)/ c design mechanis c controls m(s) of u preventi		Current design controls detection	10 - + 0 0 + 0 C	P	Reco mmen ded action (s)	Res- pon- sibility and target compl etion date	Action results					
30 40 40 50	A B B B E D L Y		0050000000		Local effect	Final effect												Action Taken	000>	00021	00+00	מטב



Risk Reduction Hierarchy:

- Risk elimination/reduction by design
- Risk reduction through safeguards
- Risk reduction through use of warnings, information and PPE



Example: Hazardous live parts



Mitigation of Risk:

Who has direct access to the ESS?



Through design?

 Enclosure to prevent access to live parts



Through safeguards

- Install in restricted location
- Guarding



Through warnings, PPE

Caution labels and information







Compliance to safety standards

- Components
 - Reliability of critical components
- System
- Constructions and testing
- Protection
 - Design
 - Safeguarding
 - Warnings & Instructions



Compliance to Codes

Safe installation and connection to utilities



Functional Safety



Software & Programmable controls relied upon for safety as ID'd in the FMEA

 Comply with appropriate safety integrity level (SIL), Class of control function, etc.

UL 1973 and Safety Approach



UL 1973, Batteries for Use in Light Electric Rail (LER) and Stationary Applications

Safety standard

Non technology specific

 Includes specific criteria for: lead acid, Nickel, Sodium Beta, Lithium ion, Flow Batteries, Electrochemical Capacitors and battery/capacitor hybrid systems

Construction requirements, Tests, and Production tests

Can be used for certification of battery systems

UL 1973 and safety approach









Safety Analysis

- Analysis of battery with single fault conditions
 - FMEA, FTA, etc.

Construction

- Materials
- Enclosure
- Electrical
 - Spacings
 - Insulation
 - Wiring and Components
- Safety controls/ protection
- Cells

Testing

- Electrical
- Mechanical
- Environmental

Markings, Instructions, Production tests

(Սլ

UL 1973 and safety approach



Safety Analysis

Applies to parts, components and circuits affecting safety



Risk assessment, FMEA, FTA, etc.

- IEC 60812, IEC 61025, etc. can be used as a guide
- ID critical safety controls
- Single fault conditions



Safety critical electronics and software

- Must meet functional safety requirements
- UL 991/UL 1998, UL 60730-1, IEC 61508
- Determine severity level, performance level or class

UL 1973 and safety approach

Battery Electrical Tests

Overcharge

Short Circuit

Battery Mechanical Tests

Static Force

Impact

Overdischarge Protection

Imbalanced Charging

Temperature & Operating Limits Check

Drop Impact

Wall Mount Fixture/ Handle Test

Mold Stress

Dielectric Voltage Withstand

Continuity

Failure of Cooling/Ther mal Stability System

Battery Environmental Tests

Resistance to Moisture

Salt Fog

Working Voltage Measurements



External Fire Exposure

Internal Fire Exposure



Introduction to UL 9540



UL 9540 - Scope



Energy storage systems and equipment:

- Safety Standard
- Includes energy storage systems that are -
 - standalone to provide energy for local loads;
 - in parallel with an electric power system, electric utility grid; or
 - able to perform multiple operational modes.
 - for use in utility-interactive applications in compliance with IEEE 1547 and IEEE 1547.1 or
 - other applications intended to provide grid support functionality,
 - may include balance of plant and other ancillary equipment of the system,





Types of Energy Storage Systems



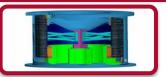
Electrochemical (e.g. batteries)

• UL 1973



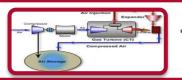
Chemical (e.g. hydrogen storage)

CSA FC1, NFPA 2, UL 2200, etc.



Mechanical (e.g. fly wheel system - under development)

ASME B & PV Code, ASME B31 piping codes



Thermal (under development)





Utility Grid Interaction Requirements



Operate safely through various conditions

- Compliance to UL 1741 and
- Referenced requirements of IEEE 1547 and IEEE 1547.1
- Requirements for special purpose utility interactive features



Tests & Updates

- Tests of UL 1741
- bulletin out to update UL 1741 to include a supplement for advanced grid support utility interactive inverter requirements to address the changing needs of the electric utility like CA Rule 21, HI and AZ.





Enclosures & Guarding

Walk in systems



Electrical



Fluid handling & containment



Fire detection & suppression

Dependent upon size and location, etc., of energy storage system



Markings, signage and instructions





ES system technology Tests



Electric tests

- Normal operations
- Dielectric voltage withstand
- Grounding and bonding
- Insulation resistance



Mechanical tests

- Over speed test
- Faulted securement test



Fluid containment tests

- Leakage
- Strength



Environmental tests

UL 9540 - Status



July 2015

ANSI UL 9540

1st Ed Bulletin

Published in June 2015

4th quarter 2015 ANSI UL 9540 1st Ed. Publication

0

June 30, 2014 UL 9540

- Published as an OOI
- Non-consensus standard



Certification options





Certification and Labelling Options



Why bother with 3rd party certification/labelling?

What does certification/ labelling entail?

- Ease of installation
- Local requirement AHJ
- Listing Certification Process
 - Compliance to UL 9540
 - Listed under UL CCN (FTBW)
 - Ongoing production inspection
 - UL Listing mark
- Field Evaluation Labelled
 - Conducted on installed product with cooperation of AHJ
 - Non-destructive evaluation
 - No production inspections
 - Field label marking





DOE and Code Activities

US DOE Activities



US DOE Work:

Safety Work Shop: February 18, 2014 in Albuquerque NM

- PNNL 23578, Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States (August 2014)
- PNNL 23618, Inventory of Safety Related Codes and Standards for Energy Storage Systems (September 2014)
- US DOE Energy Storage Safety Strategic Plan (December 2014)

Energy Storage Safety Working Group (ESSWG) (March 2015)

- Working Groups to address strategic objectives:
 - Safety Validation and Risk Assessment R&D Working Group
 - Codes and Standards Working Group
 - Safety Outreach and Incident Response Group

Code Activities



NFPA Activity:

- NFPA 70 EESS task group
 - New NEC Article (706 Energy Storage Systems)
 - Article accepted for 2017 NEC & will go through development process
- NFPA 1
 - Proposal for EESS sent as placeholder for code cycle
- New installation standard for EESS (future project)

ICC Activity:

- ICC's Fire Code Action Committee's WG on Battery & Energy Storage Systems
 - Develop revised language to propose for ICC IFC and IRC addressing EESS

THANK YOU.

847-664-3782



Laurie B. Florence
Principal Engineer – Large Format Batteries, Fuel
Cells and Capacitors
Commercial and Industrial: EP & C
UL LLC
Laurie.b.florence@ul.com